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Re: Final Report - Questar Site, Naples, Utah

At your request we performed a limited hydrogeologic investigation of the Questar facility at Naples, Utah. The purpose of this investigation was to:

1) determine the ground water flow direction and the hydraulic gradient of the shallow, unconfined aquifer beneath the Questar property, and

2) estimate the hydraulic conductivity (K) and seepage velocity of the upper portion of the unconfined aquifer.

The results of our study are summarized below.

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Ground Water Flow Direction:

A ground water flow direction of 120 degrees (south-east) was determined by triangulating the relative water level elevations and surveyed well locations for monitoring wells MW-2, MW-3, and MW-4 (Figure 1). Well elevations were provided by Questar and

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water level measurements were measured by Mayo and Associates. Surveyed well elevations and water level measurements and other data are listed below:

Monitoring Well	Well elev. (measuring point)	Depth to Water Table	Water Table Elevation
MW-2	99.72 feet	6.46 feet	93.26 feet
MW-3	103.17 feet	5.76 feet	97.41 feet
MW-4	99.97 feet	6.65 feet	93.32 feet

Hydraulic Gradient:

A hydraulic gradient of 0.016 was determined using the same triangulation data discussed above.

Hydraulic Conductivity:

The hydraulic conductivity was calculated on the basis of a single slug test performed on MW-4 on February 24, 1994. Prior to performing the test the MW-4 was purged by bailing for 2 hours. Approximately 40 gallons of water was removed during this time. The slug test was performed by injecting 4 gallons of water into the well and measuring the water level decline for a period of 1/2 hour. Measured water levels vs. time are illustrated in the following figure and listed in the following table:

seconds	water level above static level (ft.)
0	0
35	1.75
65	1.5
85	1.4
104	1.3
118	1.25
136	1.15
154	1.09
179	1.0
205	0.9
227	0.8
252	0.73
272	0.67
303	0.6
324	0.55
344	0.53
389	0.45
413	0.4
443	0.36
480	0.33
528	0.28

549	0.27
597	0.23
623	0.22
694	0.17
842	0.1
1012	0.05
1253	0.04
1740	0.025

Attempts were made to perform slug tests on additional wells at the site, but none of the other could be sufficiently developed to facilitate reliable testing. The data-set from the slug test on MW-4 was analyzed using both the Hvorslev (1951) and the Bouwer and Rice (Bouwer 1989; Bouwer and Rice, 1976) methods. Hydraulic conductivity values obtained from these two methods

1.50 ft/day (Hvorslev Method)
1.05 ft/day (Bouwer and Rice Method)

in reasonable agreement. These values also correspond well with published ranges of hydraulic conductivity for a silty sand (Freeze and Cherry, 1979). Based on the similarity of the drilling log for MW-4 to the drilling logs for the other wells on the Questar property, it is believed that the hydrogeologic conditions in the nearby wells are similar.

Because no attempt was made to isolate any specific hydrostratigraphic horizon in the completion of well MW-4, the hydraulic conductivity values determined from the slug test represent a mean value for the entire open interval of the well. Within the open interval are silty, clayey sands in the upper portion of the well, and silty gravels near the bottom of the well. This suggests that the gravely horizons likely have values of hydraulic conductivity greater than the average value for the entire well, while the silty horizons likely have hydraulic conductivities lower than the mean value for the well.

In interpreting the slug test data it must be stressed that as a general rule, slug tests are only reliable to within about an order of magnitude. There are several reasons for this uncertainty. When a well is augured in clayey sediments (such as those present on the Questar property), there is a tendency for the auger bit to smear clay particles on the borehole. This phenomenon effectively seals the borehole, as water transmission from the groundwater system to the well bore is greatly impeded. As a result, when the slug test is performed, values of hydraulic conductivity are indicated which underestimate the actual values in the groundwater system. Additionally, because the cone of influence in a slug test is usually small, macropores (fractures, root openings, animal burrows, etc.) are typically not accounted for and the slug test indicates values of hydraulic conductivity which are lower than the actual values. As a result, the values given here should probably be taken as minimum values.

Flow Velocity

A range of flow velocities were calculated for natural conditions using the hydraulic conductivity data obtained from the slug test data. The flow velocities are based on the hydraulic gradient and the hydraulic conductivity discussed previously, and an assumed value of effective porosity (0.35) as estimated using published typical values (Freeze and Cherry, 1979). Calculated flow velocities for natural conditions are 0.07 ft/day (Hvorslev Method) and (Bouwer and Rice Method). The equation used for these calculations is:

$$V = K / \text{Porosity} * \text{hydraulic gradient}$$

Because of the uncertainties in the calculated values of hydraulic conductivity (K), there is a similar degree of uncertainty in the flow velocity calculation.

Discussion

It is importance to consider that the hydraulic conductivity of the silty, sandy gravels near the bottom of the well could be substantially higher than the mean value of K determined for the well. For example, a typical sandy gravel may have a hydraulic conductivity of 200 ft/day (Freeze and Cherry, 1979). Using the hydraulic gradient of the site, a K of 200 ft/day and a porosity of 0.40 would yield a flow velocity of 8 ft/day. We do not suggest that this is the natural velocity of the coarser sediments in the bottom of the well bores, but present this calculation to demonstrate how variable groundwater flow velocity may be in layered sediments.

Ground water flow rates can be calculated for various drain designs according to Darcy's equation:

$$Q = K I A$$

where Q equals discharge, K equals hydraulic conductivity, I = hydraulic gradient and A = cross-sectional area. Using the Hvorslev approximation for K of 1.50 ft/day, the hydraulic gradient of 0.016 and a cross-sectional area of 500 square feet (250 feet * 2 feet of water in the trench), the natural flow through the trench would be 12 cubic feet per day (90 gallons per day). This calculation represents the flow of water through the trench under NATURAL gradients. It must be stressed that this does not necessarily represent flow rates for a pumped trench. Pumping water from the trench will increase the hydraulic gradient and thus increase the flow rate.

Conclusions

Because of the limited scope of our investigation and the limited hydrogeologic data available, it is difficult to precisely define ground water flow parameters beneath the Questar property. We place considerable confidence in the calculations of ground water flow directions and the ground water gradient. However, considerable uncertainty exist in our understanding of the hydraulic conductivity and natural flow velocities.

We will be please to discuss our finding in detail with you or Questar personal.

Sincerely,

Alan L. Mayo, Ph.D, R.G.

References Cited

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Bouwer, H., and Rice, R.C., 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells: Water Resources Research, v. 12, p. 423-428.

Hvorslev, M.J., 1951, Time lag and soil permeability in ground-water observations: Bulletin n. 36, Waterways Experiment Station, Corps. of Engineers, U.S. Army, 50 p.

Freeze, R. A., and Cherry, J.A., 1979, Groundwater: Prentice-Hall, 604 p.